

Influence of compost on the physical properties and organic matter fractions of a fine sandy loam throughout the cycle of a potato rotation

M. R. Carter, J. B. Sanderson, and J. A. MacLeod

Agriculture and Agri-Food Canada, Research Centre, Charlottetown, Prince Edward Island, Canada C1A 4N6
(e-mail: carterm@agr.gc.ca). Received 7 August 2003, accepted 22 December 2003.

Carter, M. R., Sanderson, J. B. and MacLeod, J. A. 2004. **Influence of compost on the physical properties and organic matter fractions of a fine sandy loam throughout the cycle of a potato rotation.** Can. J. Soil Sci. **84**: 211–218. Potato (*Solanum tuberosum* L.) rotations often require organic amendments to maintain or improve soil organic matter levels and soil physical properties. However, beneficial effects of compost can be modified by time of application and rotating tillage depth and intensity. This study was conducted to evaluate the effect of compost applied once at different phases in a 3-yr potato, barley (*Hordeum vulgare* L.), and red clover (*Trifolium pratense* L.) rotation on a range of soil physical properties and organic matter fractions for a Charlottetown fine sandy loam (Orthic Humo-Ferric Podzol) in Prince Edward Island. Soil samples (0–8 cm) were obtained during the second cycle of the rotation (after two compost applications) in the fifth year of the experiment. Soil properties were influenced by compost addition, time of compost addition, and crop phase. Compost-induced benefits in soil physical properties (bulk density, macro-porosity, oxygen diffusion rate, shear vane strength, water-filled pore space) were mainly expressed in the red clover phase of the rotation, where soil density was relatively high compared to the barley and potato phases, due to the absence of tillage. The soil physical parameters, however, were mainly within their established optimum ranges for this soil type. Soil water content at -0.033 MPa was increased by compost in the potato phase, compared to the control. Soil organic matter was influenced by both compost and crop C inputs. Compost increased soil particulate organic matter (POM) in the potato and barley phases. Due to differences in crop residue inputs, compost-related differences in organic matter were minimized in the red clover phase of the rotation. Compost addition increased potato tuber yield above the maximum yield obtained with nitrogen application. This “non-nitrogen” compost yield effect may be related to the slight, but significant, improvement in soil water-holding capacity. Overall, compost application in an intensive 3-yr potato rotation provided benefits for potato productivity and in both soil physical and biological properties.

Key words: Soil organic carbon, particulate organic matter, soil physical properties, compost amendment, potato yield, eastern Canada

Carter, M. R., Sanderson, J. B. et MacLeod, J. A. 2004. **Incidence du compost sur les propriétés physiques et les fractions de matière organique dans un fin loam sablonneux pendant un cycle d'assolement avec pomme de terre.** Can. J. Soil Sci. **84**: 211–218. Les assolements avec pomme de terre (*Solanum tuberosum* L.) exigent souvent des amendements organiques pour que le sol garde ou améliore la quantité de matière organique et ses propriétés physiques. Toutefois, le moment de l'application ainsi que la profondeur et l'intensité des labours peuvent modifier les avantages du compost. La présente étude devait préciser les conséquences de l'application de compost à divers moments lors d'un assolement de trois ans incluant la pomme de terre, l'orge (*Hordeum vulgare* L.) et le trèfle rouge (*Trifolium pratense* L.) sur diverses propriétés physiques du sol et sur les fractions de la matière organique dans un fin loam sablonneux Charlottetown (podzol orthique humo-ferrique) de l'Île-du-Prince-Édouard. Les auteurs ont prélevé des échantillons (de 0 à 8 cm de profondeur) pendant la deuxième partie de l'assolement (après deux applications de compost), la cinquième année de l'expérience. L'addition de compost, le moment où l'on ajoute ce dernier et le type de culture exercent une influence sur les propriétés du sol. Les propriétés physiques (masse volumique apparente, proportion de pores macroscopiques, taux de diffusion de l'oxygène, résistance au soc de charrue, proportion de pores remplis d'eau) qu'améliore le compost se remarquent surtout durant la culture du trèfle rouge, où le sol est relativement plus compact que durant la culture de la pomme de terre ou de l'orge, parce qu'il n'y a pas eu labour. Les paramètres physiques du sol restent néanmoins à l'intérieur de leur fourchette optimale pour ce type de sol. L'addition de compost lors de la culture de la pomme de terre porte la teneur en eau du sol à $-0,033$ MPa comparativement au sol témoin. La concentration de matière organique subit l'influence du compost et du C apporté par la culture. Le compost augmente la concentration de particules de matière organiques lors de la culture de la pomme de terre et de l'orge. La diversité des déchets de culture a minimisé la variation de la concentration de matière organique attribuable au compost durant la culture du trèfle rouge. L'addition de compost porte le rendement de tubercules de pommes de terre au-delà du rendement maximal obtenu avec l'application d'un engrais azoté. Cet effet pourrait résulter de la légère mais significative amélioration de la capacité de rétention de l'eau attribuable au compost. En général, l'application de compost dans le cadre d'une rotation intensive de trois ans se traduit par des avantages au niveau de la productivité et des propriétés physiques et biologiques du sol.

Mots clés: Carbone organique du sol, addition de compost, rendement en pommes de terre, est du Canada

Abbreviations: AHC, acid-hydrolyzable carbohydrate; MBC, microbial biomass C; MWD, mean weight diameter; ODR, oxygen diffusion rate; POM, particulate organic matter; WSC, water-soluble carbohydrates

Potato (*Solanum tuberosum* L.) rotations are often characterized by low levels of soil organic matter and consequently exhibit a poor soil physical condition. This is attributed to relatively low organic C inputs and the generally sandy soil types associated with potato production, which have a limited capability to retain organic C (Carter et al. 2003a). Consequently, the use of organic amendments is a common feature in intensive potato production systems (e.g., Gagnon et al. 2001; Grandy et al. 2002).

Organic amendments can provide a ready source of nutrients and organic matter, and provide benefits associated with an improvement in soil physical properties. Long-term studies with organic amendments have demonstrated the benefits to soil physical properties for both soil physical form and stability (Christensen and Johnston 1997). In addition, although more difficult to document, the improvement in the soil physical condition associated with the organic amendment may also provide a yield benefit, especially for shallow-rooted root crops. Johnston (1990; cited in Christensen and Johnston 1997) noted that potato yield could benefit from organic amendments through relatively small improvements in the soil water-holding capacity. Porter et al. (1999) showed that organic amendments in combination with irrigation produced benefits in both potato yield and soil properties.

In Prince Edward Island, fine sandy loam soils used in potato rotation can have low concentrations of organic matter due to reduced crop residue in the potato phase of the rotation (Carter and Sanderson 2001). Compost is one organic amendment advocated in recent years to offset soil organic matter decline (Henry 1995). Field studies in Prince Edward Island, comparing the addition of mulches and compost to potato, showed that while only straw mulching reduced soil loss, both amendments increased soil water content and improved soil physical properties (Edwards et al. 2000).

In general, practical concerns limit organic amendments to one application per cycle for intensive 3-yr potato rotations. Studies have been established in Prince Edward Island to assess the optimum timing of compost application in potato rotations (Sanderson et al. 2003). Possible benefits to soil properties by compost addition, however, may influence one rotation phase only and may not extend over the full cycle of the rotation. Variation in C inputs via crop residues at different phases of the rotation may influence the compost effect on soil properties. Thus, timing of compost application within the rotation may also influence soil response. Temporal changes in soil biological attributes are commonly observed in crop rotations (e.g., Bolinder et al. 1999; Campbell et al. 1999; Willson et al. 2001). For potato rotations, the use of rotating tillage operations utilizing various degrees and depth of tillage are additional factors impacting on temporal change in soil properties (Carter et al. 1998). The general objective of this study was to determine the effects and contribution of compost application in a 3-yr potato rotation on potato yield and soil properties. Specific objectives of the study were (1) to assess the effect of compost application on soil physical properties and organic matter fractions; (2) to assess the influence of crop phase on soil

response; and (3) to determine the benefit of improved soil physical conditions due to compost application on overall potato yield.

MATERIALS AND METHODS

Experimental Site

Experiments were conducted between 1992 and 1996 on a commercial field near the Agriculture and Agri-Food Canada, Harrington Research Farm (63°10'W, 46°21'N) in Prince Edward Island. The soil was a fine sandy loam (Orthic Humo-Ferric Podzol) (MacDougall et al. 1988) that contained 600, 290, and 110 g kg⁻¹ of sand, silt and clay, respectively, in the 0- to 30-cm soil depth. At the onset of the experiment, in the spring of 1992, ground cover on the field site was composed primarily of timothy (*Phleum pratense* L.). Some soil fertility properties at the initiation of the study were as follows: pH, 6.1; organic C, 18.6 g kg⁻¹, and extractable (Mehlich III) P, K, Ca, and Mg at 85 µg g⁻¹, 36 µg g⁻¹, 629 µg g⁻¹, and 66 µg g⁻¹, respectively.

Experimental Treatments

The study was part of a larger and more extensive study to assess timing of compost addition in combination with increasing N application on potato productivity in Prince Edward Island (Sanderson et al. 2003). The experiment followed a split/split/split plot design with three factors and four replications. The three factors were as follows: (1) phase of rotation, (2) compost application time, and (3) N rate applied to the potato crop phase only with four replications. The main plots (77.2 m × 22.7 m) contained three phases of rotation: (1) Barley (*Hordeum vulgare* L.) under-seeded to red clover (*Trifolium pratense* L.), (2) Red clover (red clover was direct-seeded in 1992 at the initiation of the experiment), and (3) Potato (*Solanum tuberosum* L.; variety, Russet Burbank). Non-inversion tillage (one-pass tandem disc and S-tine harrow, 15-cm depth) was used in the spring (May) to prepare the land for barley seeding. The barley crop (under-seeded to red clover) was harvested and straw was removed in late August. Barley grain yield ranged from 2.3 to 4.1 Mg ha⁻¹ with a mean and SE of 2.9 ± 0.64 Mg ha⁻¹. In the following year, the first cut of red clover was removed in late June (DM yield ranged from 1.4 to 5.3 Mg ha⁻¹ with a mean and SE of 3.9 ± 1.34 Mg ha⁻¹) and the regrowth incorporated (by moldboard plough, 25-cm depth) in late October. In the spring after red clover, several passes of secondary tillage (tandem disc and S-tine harrow, 15-cm depth) were used to prepare the land for potato planting. Potato management practices are outlined in Sanderson et al. (2003). Potato yields were measured by harvesting two rows (6.4 m long) in each plot in mid- to late-October. Tubers were graded to obtain marketable yield.

Compost treatments were applied at different times in the rotation, but once only during each 3-yr rotation cycle. Six sub-plots (22.7 m × 11.4 m) were established to assess time of compost application. Compost subplots were further subdivided into six sub-sub-plots of 7.6 m × 3.6 m with N applied at five levels in 60 kg ha⁻¹ increments from 0 to 240 kg ha⁻¹. Additional fertilizer broadcast applied over the

entire experimental area was as follows: 60 kg P ha⁻¹ and 112 kg K ha⁻¹ in 1992, and 39 kg P ha⁻¹ and 74 kg K ha⁻¹ in 1996. Further details of the experiment are given in Sanderson et al. (2003).

For the purposes and objectives of the present study not all of the above plots were sampled. Investigations were confined to use of three compost application times and plots receiving 120 kg N ha⁻¹ only. Table 1 outlines the crop phase and time of compost application. For the plots sampled in this study, compost was applied in 1992 and 1995 to each phase of the rotation. The soil sampling occurred in October 1996, 1.5 yr after the second compost application.

Compost Information

Compost (potato, sawdust, manure volume ratio of 3:3:1) was prepared following the method of Henry (1995) and applied at 12.8 to 16.8 Mg dry matter (DM) ha⁻¹ (Table 2). Further details are given in Sanderson et al. (2003). Table 2 gives the compost's chemical characteristics. Compost was applied with a commercial manure spreader modified with a catch pan at the back of the floor chain to ensure uniformity of spread.

Soil Sampling and Analysis

In early October 1996, at the end of the fifth year of the study (after two compost applications — see Table 1), three soil cores (8 cm inside diameter) per plot were obtained from the 0–8 cm soil depth of each treatment. This depth was chosen as it provides the most benefit to root growth in these relatively shallow soils. Cores were obtained when the soil was near field capacity to prevent soil shattering. The cores were wrapped in plastic and stored at 4°C. Soil samples (0–8 cm) were also collected with a trowel adjacent to the cores (three per plot) and composited. A portion of the trowel-sampled soil was air-dried and the remainder stored field moist at 4°C.

The cores were subjected to a sequence of methods (Carter 1992) conducted on the same core. First, soil water desorption was determined using a tension medium of glass beads (30-µm diameter), at a tension of 6 kPa, to provide an estimate of macro-pore volume (equivalent pore diameter > 50 µm) (Topp et al. 1993). Second, air permeability was determined on the soil cores, equilibrated at 6 kPa tension, using a low (to reduce turbulent flow) constant air pressure of 0.25 kPa to characterize macro-pore continuity (Carter 1992). Third, oxygen diffusion rate (ODR) was measured in the cores, immediately after the air permeability measurement, using platinum electrodes and an effective voltage of 0.65 mV (Carter 1992). Fourth, torvane shear strength was measured on the surface of each core using a shear vane with a measurement range of 0–200 kPa. The shear vane was composed of eight vanes, 19 mm wide and 29 mm long. At the completion of the above sequential tests, the cores were dried at 105°C and dry soil bulk density determined.

The field-moist soil samples obtained with the trowel from each plot were passed through a 4.8-mm sieve. Soil structural stability was determined using a wet-sieving method (Angers and Mehuys 1993). Duplicate soil sub-sam-

Table 1. Crop sequences and phases of the 3-yr potato rotation and time of compost application

Experimental crop phase	Year				
	1992	1993	1994	1995	1996
Sequence 1	↓ B	RC	P	↓ B	RC
Sequence 2	RC ↓	P	B	RC ↓	P
Sequence 3	↓ P	B	RC	↓ P	B

Each phase of the rotation was present each year (B = barley; RC = red clover; P = potato). Compost applied (↓) in 1992 and 1995 at specific times: spring (May) before B seeding, in fall (October) prior to RC incorporation, and in the spring (May) just before P planting. Soil sampling occurred in late October 1996.

ples (30 g) were placed on a nest of sieves (2.00, 1.00, 0.50, and 0.25 mm) then the sieves were placed in a wet-sieving apparatus and the soil wet-sieved under water for 10 min. After sieving, the stable aggregates and sand particles remaining on each sieve were rinsed into a pre-weighed tin, dried overnight at 45°C, and then weighed. After drying, the sieved samples were placed back onto the original sieves and sieved for 5 min. in a 0.4% solution of NaOH. A spatula was used to break up any remaining aggregates. After washing in water, the primary particles on each sieve were then rinsed into a pre-weighed tin, oven-dried (105°C) overnight, and weighed. The water-stable aggregate mean weight diameter (MWD) was calculated according to the method of Angers and Mehuys (1993).

Soil moisture constant at “field capacity” was estimated on air-dry trowel-sampled soil, sieved to pass a 2-mm sieve, using the standard pressure plate method (0.033 MPa) (Topp et al. 1993).

For the soil organic matter fraction measurements, the trowel-sampled soil was used. Soil samples were air-dried prior to measurement of soil organic matter, POM, and soil carbohydrates. Soil total C and N were determined by dry combustion on soil ground and sieved at 0.5 mm. The POM, also termed “macro-organic matter”, was determined using a modification of the method outlined in Carter et al. (2003a). Briefly, 25 g of air-dry soil (2 mm) was mixed with distilled water (100 mL) and 10 glass beads (5-mm diameter). The samples were shaken for 12 h on a reciprocal shaker. The samples were wet-sieved with distilled water through a 53-µm sieve into a 600-mL beaker. The fractions were dried at about 50°C to constant weight. The POM-C and -N contents were determined by difference between whole soil C and N concentration, and C and N concentration of the < 53 µm fraction. Soil water-soluble carbohydrates (WSC) and dilute acid-hydrolyzable carbohydrates (AHC) were determined using methods outlined in Angers et al. (1993). Briefly, WSC were extracted from a soil (2–3 g) distilled H₂O (10 mL) mix after heating at 85°C for 24 h, while extraction of AHC followed the same procedure but used 1.5 M H₂SO₄ (neutralized with NaOH after extraction) in place of H₂O. After filtration both carbohydrate extracts were determined using the alkaline-ferricyanide method.

Soil microbial biomass C (MBC) was determined on moist trowel-sampled soil using the fumigation-direct

Table 2. Chemical characteristics of the compost utilized in the study

Year of application ²	Rate of DM application (Mg ha ⁻¹)	C:N ratio	pH	Nutrients (g kg ⁻¹ DM)		
				Nitrogen	Phosphorus	Potassium
1992	12.8	15.3	6.6	1.34	0.55	1.04
1995	16.8	12.4	6.6	1.20	0.36	1.00

²See Table 1 for compost application time in 1992 and 1995.

extraction method (Voroney et al. 1993). Duplicate moist soil samples (50 g) were fumigated for 24 h with ethanol-free CHCl₃. After fumigation, the samples along with non-fumigated soil samples were extracted with 0.5 M K₂SO₄ (2:1 solution:soil ratio). After filtering, the soluble C was measured by persulphate-UV digestion on a TRAAC 800 autoanalyser. Microbial biomass C was estimated by dividing the difference in soluble C between fumigated and non-fumigated soils by a "k" factor of 0.25.

Statistical Analysis

The data were analysed as a split-plot design, with the rotation crops as the main plots and time of compost application as the sub-plots. Data were subjected to analysis of variance using standard procedures and software (Genstat 5 Committee 1993). Orthogonal contrasts were used to test control versus compost application within each crop.

RESULTS

Compost Addition and Soil Physical and Biological Properties

For soil physical properties, compost addition significantly ($P = 0.05$) decreased soil density parameters such as bulk density and shear vane (soil strength) in the red clover phase of the rotation, compared to the control (Fig. 1). Soil aeration parameters were also significantly ($P = 0.05$) influenced by compost addition (Fig. 2). Soil water-filled pore space was decreased during the red clover phase only, while oxygen diffusion rate and soil macro-porosity were increased by compost addition in both the barley and red clover phases. Differences between control and compost treatments for all of the above soil physical parameters were not evident during the potato phase of the rotation. Mean-weight diameter for wet-sieved aggregates was not significantly influenced by the compost additions (Table 3).

Soil water content at -0.033 MPa was significantly increased ($P = 0.012$) by compost additions (25.8% mass basis), compared to the control (22.4%), in the potato year (data not shown).

For the soil biological properties, concentration of organic C and total N and POM-C were significantly ($P = 0.05$) increased by compost addition in the barley and potato phases (Table 3). Some of these differences were also evident when organic matter was expressed on a volume basis (Fig. 3). Other soil biological properties such as AHC and MBC were not significantly affected by compost application (Table 3). Water-soluble carbohydrates, however, were significantly ($P = 0.05$) increased by compost addition in each phase of the rotation (Table 3).

Crop Rotation Phase and Soil Physical and Biological Properties

In addition to compost application, comparison of the main plots (rotation phase) showed that soil physical properties were significantly ($P = 0.05$) influenced by crop rotation phase. Soil bulk density (Fig. 1a), soil shear vane (Fig. 1b), and soil water-filled pore space (Fig. 2b) were significantly lower in the potato phase, compared to the barley and red clover phases. In contrast, the macro-pore volume (Fig. 2a) was increased in both the potato and barley phases, compared to the red clover phase. The oxygen diffusion rate was lower in the barley phase compared to the red clover and potato phases (Fig. 2c). Although differences in aggregate stability were not evident due to compost additions, the mean wet-sieved aggregate MWD was significantly ($P = 0.019$) greater under the potato phase (1.45 mm), compared to that found under the barley and red clover phase (1.12 mm) (Table 3).

For the soil biological indices, rotation phase significantly ($P = 0.05$) influenced many of the organic matter indices. An increased level of total organic C and total N was evident in the barley and red clover phase, compared to the potato phase (Fig. 3b). The mass of POM-C increased under red clover, compared to the other two phases of the rotation. This result was not evident for POM-N (Fig. 3a).

Soil Physical Effect on Mean Potato Yield

Without fertilizer N, potato yield was significantly ($P = 0.05$) increased from 22 to 25 Mg ha⁻¹ by compost additions (Fig. 4). The potato yield without compost obtained at 120 kg N ha⁻¹ was 31 Mg ha⁻¹. This was significantly ($P = 0.05$) less than that found for compost at the same rate of N (34 Mg ha⁻¹). Application of compost significantly ($P = 0.05$) influenced both the maximum potato yield and the level of fertilizer N required to obtain maximum yield (Fig. 4). The maximum potato yield obtained in response to increased fertilizer N application was 36 Mg ha⁻¹ (at 250 kg N ha⁻¹) without compost and 39 Mg ha⁻¹ (at 213 kg N ha⁻¹) for compost application.

DISCUSSION

Soil properties were influenced by both compost additions, and soil and crop management. The study illustrates that for these intensive 3-yr potato rotations, the use of companion crops (i.e., barley and red clover) mainly for organic matter addition and the use of rotating tillage depth and intensity (i.e., shallow, non-inversion for barley vs. deep tillage for potato) significantly influenced the benefit of the compost additions.

Compost and Soil Physical Properties

Compost-induced changes in soil physical parameters (Figs. 1 and 2) were mainly evident in the red clover phase, when the

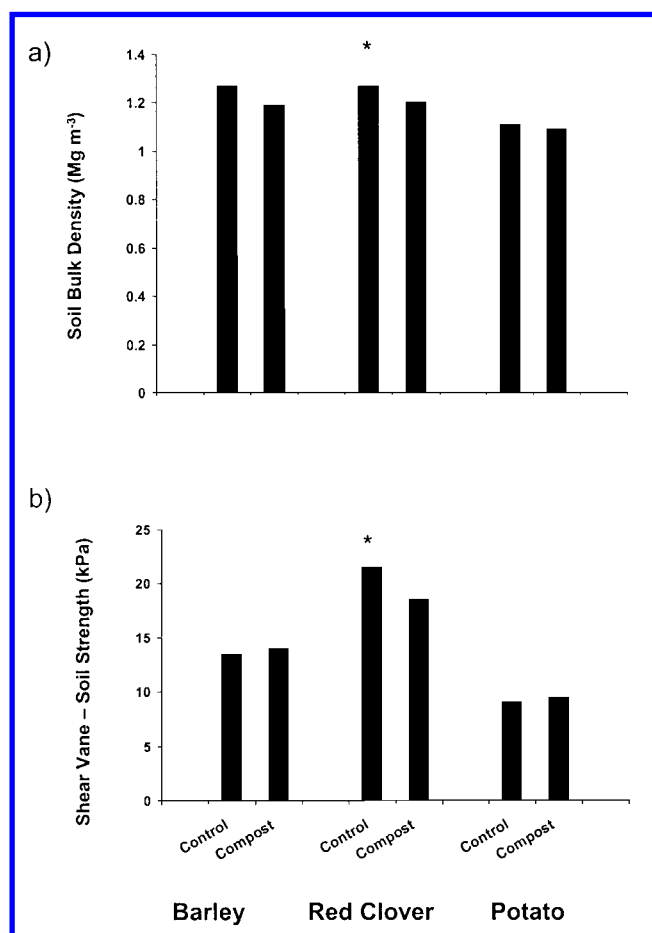


Fig. 1. Soil density parameters for the 0- to 10-cm soil depth in the control and compost treatments, for each phase of the 3-yr potato rotation, measured after 5 yr: (a) bulk density and (b) shear vane strength. *indicates statistically different ($P < 0.05$) for the same crop phase and parameter.

soil was relatively undisturbed from tillage events. Previous studies on similar soil types in Prince Edward Island indicate that relative compaction after tillage gradually increases due to consolidation, traffic, and wetting/drying cycles (Carter 1990). Under such conditions, the previous year (compost added in barley phase, Table 1) compost additions would help resist, to some degree, the propensity for soil density increase when tillage is omitted (red clover phase). In contrast, under relatively intensive tillage (i.e. potato phase) the effects of compost on soil physical properties were marginalized, as tillage had the dominate effect on soil macro-structure.

The soil physical condition was optimum for potato growth as the various properties fell inside their critical range for this soil type (Carter 1992; Carter et al. 1998). For example, soil macro-porosity exceeded 12% volume while ODR exceeded $45 \mu\text{g m}^{-2} \text{s}^{-1}$, which is a critical value associated with optimum yield of potato in Atlantic Canada (Saini 1976). In addition, soil shear strength was below the critical level of 32 kPa for this fine sandy loam soil type (Carter 1992). Soil water-filled pore space was generally below the 66% value associated with a reduction in soil N

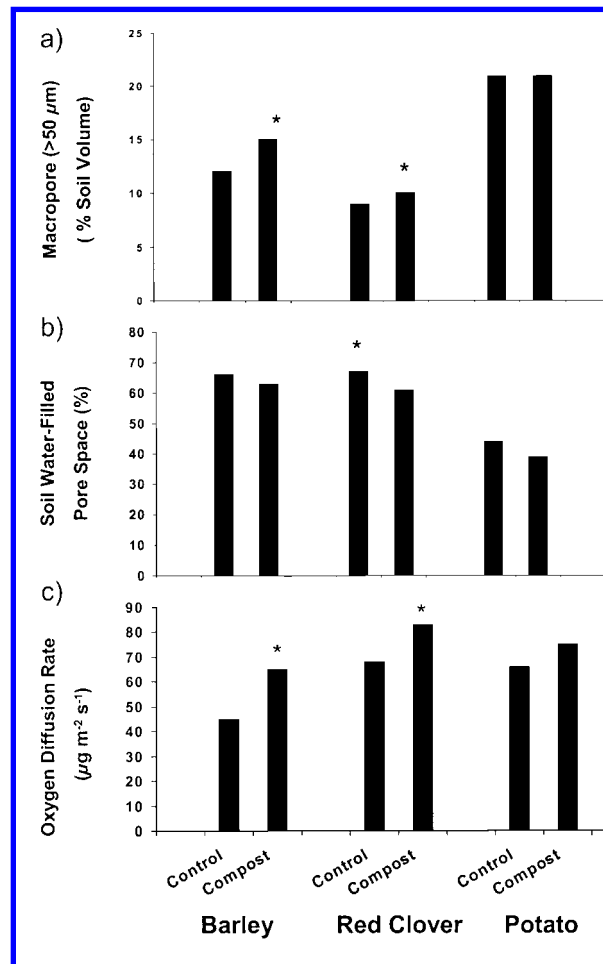


Fig. 2. Soil aeration parameters for the 0- to 10-cm soil depth in the control and compost treatments, for each phase of the 3-yr potato rotation, measured after 5 yr: (a) macro-pore (>50 μm) space, (b) water-filled pore space, and (c) oxygen diffusion rate (ODR). *indicates statistically different ($P < 0.05$) for the same crop phase and parameter.

mineralization (e.g., Reynolds et al. 2002). Only in the red clover phase was soil physical condition marginal due to increases in soil density and strength.

Soil structural stability was not influenced by compost additions although it varied with crop phase in the rotation. Other studies have reported that soil structural changes may be short-lived in organic amendment studies (Gagnon et al. 2001; Grandy et al. 2002) or crop rotation comparisons (Angers et al. 1999) conducted on sandy or coarse to medium-textured potato soils. Such variations are often associated with variations in soil climatic conditions (Angers et al. 1999). Small increases in structural stability have been observed under compost application in field studies in Prince Edward Island (Edwards et al. 2000).

Compost and Soil Organic Matter Fractions

In contrast to soil physical properties, changes in soil organic matter fractions were more related to crop species and C inputs than tillage intensity. Compost-induced increases were mainly evident in POM-C in the barley and potato phases, and in water-soluble carbohydrates in all three crop

Table 3. Comparison of soil biological properties under the control (no compost) and compost treatment in the three phases of the 3-yr potato rotation on a fine sandy loam in Prince Edward Island^z

Crop phase and treatments	Organic C (g kg ⁻¹)	POM-C (g kg ⁻¹)	Total N (g kg ⁻¹)	POM-N (g kg ⁻¹)	MBC (µg g ⁻¹)	WSC (mg kg ⁻¹)	AHC (g kg ⁻¹)	MWD (mm)
<i>Barley</i>								
Control	19.8	5.2	1.14	0.11	196	672	5.6	1.01
Compost	22.6*	10.0*	1.47*	0.42	204	806*	5.8	1.09
SE	0.55	0.43	0.048	0.100	23.6	27.9	0.27	0.118
<i>Red clover</i>								
Control	20.4	10.3	1.22	0.36	211	660	5.6	1.16
Compost	22.3	12.1	1.35	0.40	257	751*	5.8	1.21
SE	0.56	1.00	0.07	0.141	22.1	24.4	0.21	0.104
<i>Potato</i>								
Control	19.3	7.3	1.23	0.43	131	620	5.3	1.46
Compost	20.5*	10.7*	1.22	0.51	170	678*	6.1	1.44
SE	0.18	0.71	0.023	0.044	25.0	34.7	0.14	0.160

^z SE = standard error of the mean. Biological properties: POM = particulate organic matter; MBC = microbial biomass C; WSC = water-soluble carbohydrates; AHC = acid-hydrolyzable carbohydrates; MWD = mean weight diameter of water stable aggregates.

*Indicates significant difference at $P = 0.05$ between control and compost for the same crop phase.

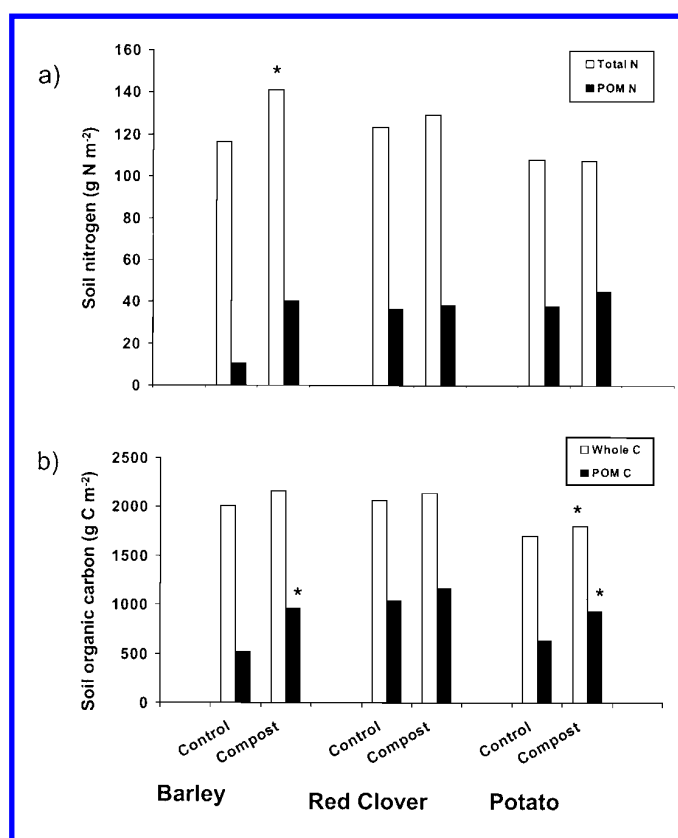


Fig. 3. Soil organic matter indices for the 0- to 10-cm soil depth in the control and compost treatments, for each phase of the 3-yr potato rotation, measured after 5 yr: (a) total N and POM-N, and (b) organic C and POM-C. *Indicates statistically different ($P < 0.05$) for the same crop phase and parameter.

phases (Table 3, Fig. 3). The latter are considered to be a labile C fraction sensitive to soil management and C inputs (Angers et al. 1993). Willson et al. (2001) and Fortuna et al. (2003) noted an increase in POM-C from compost additions

in coarse-textured soils. In comparison to the barley and potato phases, the relatively large input of crop residue C under red clover would tend to minimize or dilute the compost effect on soil POM-C in this phase of the rotation (Fig. 3). Angers et al. (1999) and Carter et al. (2003b) indicated in long-term studies on Charlottetown fine sandy loams that estimated annual C inputs were 90–150, 120–300, and 240–600 g C m⁻² for potato, barley, and red clover, respectively. Under these scenarios, the estimated 300 g C m⁻² from the compost addition per rotation cycle would probably be more evident, in comparison to the control treatment, in the potato and barley phases, rather than the red clover phase.

Grandy et al. (2002) noted that organic matter additions in fine loams under intensive potato rotations in Maine, via use of companion crops and compost additions, increased soil organic C concentration mainly in the light fraction C pool. Angers et al. (1999) demonstrated a similar finding for a range of potato cropping sequences in Prince Edward Island. In the present study, the increased soil organic C due to compost or crop residue inputs was mainly due to increases in POM-C (Table 3, Fig. 3). Soil organic C levels of 18.6 g kg⁻¹ at the initiation of the study would indicate that the clay plus silt particles were saturated with organic C, as previous studies have estimated that the capacity factor for a Charlottetown fine sandy loam is approximately 18.2 g kg⁻¹ (Carter 2002; Carter et al. 2003a). Under such conditions, organic C and N accumulation in this sandy loam soil type would be contingent on maintaining the POM fraction. This underlines the need for ongoing C inputs in these intensive potato rotations as POM has a relatively short turnover time relative to clay and silt associated organic matter (Carter 2002). In this regard, the generally accepted annual C input of > 200 g C m⁻² to maintain soil organic matter levels in sandy loams would be met by the 3-yr rotation assessed in this study (Parton et al. 1996; Carter et al. 2003b). Angers et al. (1999) showed in a comparison of several potato rotations in long-term studies on a Charlottetown fine sandy loam that rotations that supplied estimated C inputs in excess of

240 g C m⁻² yr⁻¹ maintained the original level of soil organic C. The same study showed that a 3-yr rotation (barley-red clover- potato), supplying an estimated 360 g C m⁻² yr⁻¹, increased the level of soil carbon (from initial level of 16 to 17 g C kg⁻¹) over a 10-yr period.

Soil Physical Condition and Potato Productivity

Although the above individual soil physical parameters may be optimum for potato growth, as established in previous studies for this soil type (Carter 1992; Carter et al. 1998), interactions among parameters can present an advantage for the soil physical condition. Improved soil water relations as reflected in the balance between soil water-holding capacity and aeration can improve the soil physical condition for plant growth (Reynolds et al. 2002). In the present study, the ratio of macro-pore air permeability and macro-pore volume, which reflects soil permeability to water and air, was consistently high (>100 µm²) and in agreement with other studies on the same soil type (Carter 1992; Carter et al. 1998). Relatively minor increases in soil water content under compost addition, compared to the control, may provide a yield benefit. DeHaan et al. (1999) using potato bulk yield monitoring with global positioning system showed that a relatively small range (20 to 25% H₂O) in soil water content (at -0.033 MPa), across commercial potato fields in Prince Edward Island, was significantly ($P = 0.05$, $r = 0.82$) related to potato tuber yield differences of 5 to 7 Mg ha⁻¹.

The relatively small, but significant increases, in soil water content at "field capacity" in the potato phase in this study (due to compost application in the previous year), along with the other soil aeration and porosity interactions, may explain the increased potato yield above that obtained at "yield maximum with N" yield (Fig. 4). Wild (1993) illustrated how cereal grain yield increases related to soil organic matter increases could be explained by N mineralization alone, while with potato the organic matter effect on crop yield could not be totally compensated for by use of N fertilizer. Christensen and Johnston (1997) noted that soil organic matter effects on crop productivity cannot be fully replaced by increased levels of N fertilizer, as organic matter provided a yield increase above that associated with N. This "non-nitrogen" yield effect for long-term studies at Rothamsted (UK) in sandy loam soils was limited (<1 Mg ha⁻¹) for cereal grain yield, but significant (2–8 Mg ha⁻¹) for potato tuber yield. Such yield benefits for sandy loam soils were related to changes in soil porosity, consistency limits, and structural stability. For medium-textured soils the influence of compost on soil water constants demonstrates a major benefit of organic amendments in potato rotations.

CONCLUSIONS

Compost application once in the cycle of a 3-yr potato rotation was beneficial for both soil physical and biological properties, and for potato productivity. The compost influence was modified by both crop phase and tillage events. Compost had a beneficial but temporal influence on soil physical properties. Improvements in soil physical properties, related to compost addition, were mainly evident in the

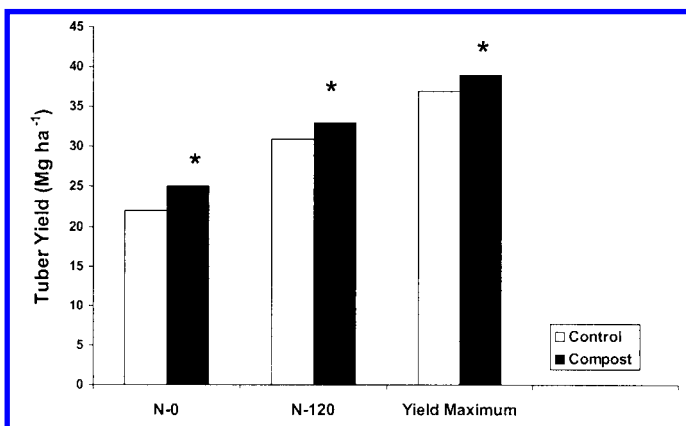


Fig. 4. Average (over 5 yr) potato tuber yield in response to no fertilizer N (N-0) and applied fertilizer N (N-120 kg N ha⁻¹) in the control (no compost) and compost treatments. Yield maximum in the larger experiment (Sanderson et al. 2003) was achieved at 250 and 213 kg N ha⁻¹ for control and compost treatments, respectively. *indicates statistically different ($P < 0.05$).

red clover phase, under a relatively dense soil condition due to the absence of tillage. Use of intensive tillage prior to and within the potato phase removed this differential in physical properties due to compost addition. Time of compost application and crop residue addition influenced the level of soil organic matter throughout the rotation cycle. The main compost effect in the potato year was associated with a slight increase in water-holding capacity. This latter "non-nitrogen" benefit probably resulted in the slight potato tuber yield increase, and would provide a potential yield benefit especially in dry years.

ACKNOWLEDGMENTS

The authors are thankful for assistance provided by Agriculture and Agri-Food Canada technical staff. This paper is Contribution No. 1024 of the Charlottetown Research Centre.

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